

Single-shot Vector Optical Field Measurement Method Using Distorted Diffraction Grating

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Measurement techniques for vector optical fields—comprising light intensity, phase, and polarization states—hold great potential for diverse applications including material characterization and biological analysis. The Transport-of-Intensity Equation (TIE) provides a non-interferometric method that retrieves a complex-amplitude distribution from several defocused intensity distributions. As an extension, we are studying a vector measurement method based on the TIE combined with a polarization camera [1]. To enable single-shot acquisition of required intensity information, we investigated a configuration using optical path separation with a linear diffraction grating [2]. However, this configuration requires multiple lenses for each of the separated optical paths, and simplicity and extensibility are limited.

In this study, we investigated another configuration employing a distorted diffraction grating [3] at the Fourier plane. By introducing a quadratic distortion to the grating pattern, the grating separates light waves with defocus lengths proportional to diffraction orders. These separated intensity distributions are used to approximate the longitudinal intensity derivative in the TIE. This approach enables to construct the rear imaging optics using a single lens, regardless of the number of optical paths. Furthermore, the use of more diffraction orders improves the approximation of the intensity derivative, which leads to more accurate retrieval of the phase distribution. The behavior of a designed optical system was validated through numerical simulations based on wave optics. A sample generating a complex amplitude distribution with spatially varying polarization was used as a measurement target. Assuming Gaussian beam illumination, we simulated light propagation through the optical system. By using the distorted grating, a 3×3 array was generated on the image plane, as shown in Fig. 1(a). The phase and polarization states were reconstructed by using the TIE and several diffraction patterns. Figs. 1(b) and (c) show estimated phase distributions and polarization states. The background region exhibits linear polarization at 45° from the x -axis, while the characters “IPLab” region exhibits elliptical polarization as expected. The retrieval error rate was approximately 10%. These results show that the target vector field is reproduced, and suggest the effectiveness of the proposed configuration.

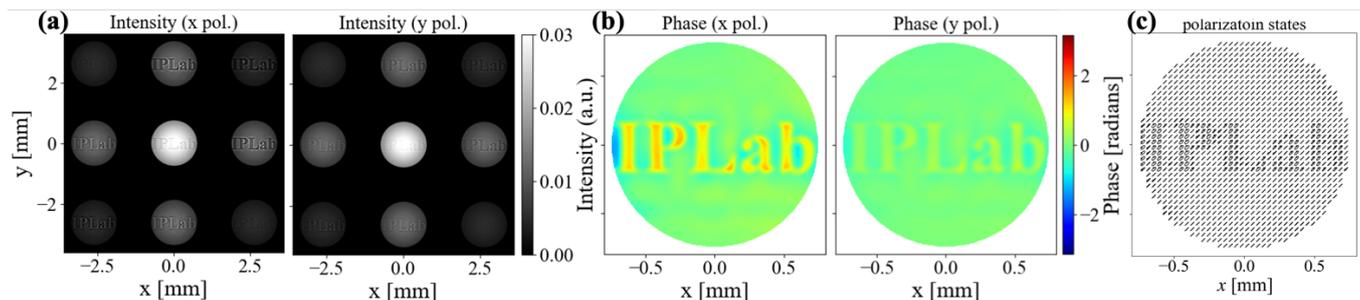


Fig. 1. Simulation results. (a) Intensity distributions of x - and y -polarization components at image plane. (b) Phase distributions of the reconstructed target field for the x - and y -polarization components. (c) Polarization state distribution of the target field calculated from the complex amplitudes at the image plane.

References

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